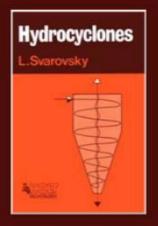
## Hydrocyclones Volume II

L. Svarovsky, G. Svarovsky





The previous volume published in 1984 has been the leading teaching text on Hydrocyclones for almost three decades.



[Chapter 7] is a glorious chapter – I'm really grateful to have access to it, and it will be a valuable contribution to the level of understanding "out there" - Mr Paul Salter, MD of Salter Cyclones Ltd

Hydrocyclones Volume II takes account of further developments and research, and once again is based on short courses now attended by over 1000 participants. The two volumes together represent a comprehensive and up-to-date reference and teaching text firmly grounded in industrial practice.

Professor L. Svarovsky has been engaged in the field of solid-liquid separation for nearly 50 years. He is currently Senior Consultant and Head of FPS Institute. G. Svarovsky is a former member of the FPS team and Technical Director at IDBS.



www.svarovsky.org/fps2

## Contents

1	PERSONAL PREFACE AND ACKNOWLEDGEMENTS	8		
1.1	From Lado	8		
1.2	From George	11		
2	Introduction	13		
2.1	THE SCOPE OF THIS BOOK	13		
2.2	THE REASONS FOR CONTINUING GROWTH IN THE USE OF HYDROCYCLONES			
2.3	PRINCIPLE AND APPLICATIONS	16		
2.4	THE FUTURE	28		
3	THEORIES OF SEPARATION AND MODELS	32		
3.1	Introduction	32		
3.2	THE EQUILIBRIUM ORBIT AND RESIDENCE TIME THEORIES	34		
3.3	THE TURBULENT TWO-PHASE FLOW THEORY	37		
3.4	CROWDING THEORY	39		
3.5	COMPARISON OF THE SIMPLE THEORIES	40		
3.6	THE REGRESSION MODELS	42		
3.7	THE DIMENSIONLESS GROUP MODEL	45		
	3.7.1 EXAMPLES OF DESIGN CHOICES	47		
3.8	ANALYTICAL FLOW MODELS	50		
3.9	NUMERICAL SIMULATIONS OF THE FLOW			
3.10	CONCLUSIONS ON MODELS	53		
4	HYDROCYCLONE INSTALLATION AND TESTING	60		
4.1	INSTALLATION OF HYDROCYCLONES			
	4.1.1 Orientation of individual units	61		
	4.1.2 Pumps, sumps and manifolding	63		
	4.1.3 Installing hydrocyclones in parallel	65		
	4.1.4 Installing hydrocyclones in series	68		

	4.1.5	TEST RIC	GS	68	
	4.1.6	Enviro	NMENTAL FACTORS AND SAFETY	71	
4.2	Hydr	OCYCLON	NE OPERATION AND CONTROL	72	
	4.2.1	INSTRUM	MENTATION AND CONTROL	73	
	4.2.2	OPERAT	TING PROBLEMS AND SOLUTIONS	76	
4.3	Hydr	Hydrocyclone testing			
	4.3.1	CONVEY SIZE	NTIONAL TESTING FOR GRADE EFFICIENCY AND CUT	77	
	4.3.2 A NEW METHOD OF TESTING HYDROCYCLONES			82	
		4.3.2.1	THE THEORY	83	
		4.3.2.2	PRACTICAL USE OF THE METHOD	85	
		4.3.2.3	EXPERIMENTAL APPARATUS	86	
		4.3.2.4	EXAMPLE OF TEST RESULTS	88	
		4.3.2.5	CONCLUSIONS	92	
	4.3.3		LE SIZE MEASUREMENT USING A FULLY TESTED CYCLONE, WITH POTENTIAL FOR ON-LINE USE	93	
		4.3.3.1	A NEW SIMPLIFIED MEASUREMENT/MONITORING OF PARTICLE SIZE WITH A HYDROCYCLONE	93	
		4.3.3.2	OTHER METHODS OR SYSTEMS FOR USING A HYDROCYCLONE AS A PARTICLE SIZE ANALYSER	97	
5	Hydr	OCYCLO	NE SELECTION AND SIZING	103	
5.1	SPECIE	FICATION	OF THE TASK FOR A HYDROCYCLONE	111	
	5.1.1	CLASSIF	ICATION, DE-GRITTING OR DE-SLIMING	113	
	5.1.2	CLARIFICATION 11			
	5.1.3	SOLIDS RECOVERY, THICKENING OR SOLIDS WASHING 11			
	5.1.4 Design and selection strategies: make your own hydrocyclone or buy one?			115	
		5.1.4.1	MANUFACTURERS' APPROACH	115	
		5.1.4.2	A DO-IT-YOURSELF APPROACH	116	
5.2	SELEC	TION FRO	M MANUFACTURERS' DATA	117	
	5.2.1	CONVER SYSTEMS	RSIONS OF CAPACITY CURVES FOR NON-AQUEOUS	120	

	5.2.2	Conversions of cut siz systems	ZE FOR DIFFERENT LIQUID/SOLID	121	
5.3	SELECTION FROM PUBLISHED GEOMETRIES 12				
	5.3.1	SIMPLIFIED PROCEDURE,	FOR LOW FEED CONCENTRATIONS	122	
	5.3.2	A PROCEDURE THAT INCI	UDES THE EFFECT OF FEED	127	
	5.3.3	ALTERNATIVE DESIGN EC	QUATIONS	132	
		5.3.3.1 PLITT'S EQUATI	ONS	132	
		5.3.3.2 MULAR AND JUI	LL	133	
		5.3.3.3 ARTERBURN (K	rebs Engineers)	134	
	APPEN LEVEL		SIZES TAKEN AT DIFFERENT %	135	
6	Hydr	OCYCLONE NETWORKS, S	ERIES AND RECYCLES	139	
6.1	INTRO	DUCTION			
6.2	SERIES CONNECTIONS ON OVERFLOW			142	
	6.2.1	OVERFLOW SERIES WITH	PARTIAL OVERFLOW RECYCLE	146	
	6.2.2	OVERFLOW SERIES WITH	UNDERFLOW RECYCLES	148	
6.3	SERIE	CONNECTIONS ON UNDER	RFLOW	151	
	6.3.1	Underflow series with	H OVERFLOW RECYCLE	155	
6.4	SERIES CONNECTIONS ON BOTH OUTLETS 15				
	6.4.1	A THREE-STAGE, BALANC CLASSIFICATION	ED ARRANGEMENT FOR	157	
	6.4.2	A TWO-STAGE THICKENIN	NG FOLLOWED BY CLARIFICATION	158	
	6.4.3	A TWO-STAGE CLARIFICA	TION FOLLOWED BY THICKENING	160	
6.5	MASS BALANCE CALCULATIONS				
	6.5.1	A SHORT CUT METHOD FO	DR SYSTEM EFFICIENCY	162	
	6.5.2	A COMPUTERISED METHO	DD	166	
		6.5.2.1 METHOD OF CA	LCULATION	167	
		6.5.2.2 PROGRAM DESC	RIPTION	170	
		6.5.2.3 EXAMPLES OF U	SE	172	

7	HYDE	ROCYCLONES IN COUNTER-CURRENT WASHING	179	
7.1	INTRO	Introduction		
7.2	THE P	The pumping arrangements		
7.3		ADVANTAGES AND CAPABILITIES OF A COUNTER-CURRENT WASHING SYSTEM		
7.4	MASS	BALANCE CALCULATIONS FOR THE SOLIDS	187	
	7.4.1	A SHORT CUT METHOD FOR SYSTEM PARTICLE SEPARATION EFFICIENCY CALCULATIONS	188	
	7.4.2	A DETAILED MASS BALANCE FOR SOLIDS AND LIQUID	191	
7.5	WASH	ING EFFICIENCY CALCULATIONS	195	
	7.5.1	EXAMPLES OF WASHING EFFICIENCY CALCULATIONS	198	
7.6	WASH	ING TRAIN DESIGN RECOMMENDATIONS	200	
	7.6.1	WASHING EFFICIENCY	201	
	7.6.2	Wash liquid requirement	201	
	7.6.3	SETTING OF THE FLOW RATIOS	201	
	7.6.4	MASS TRANSFER FROM THE SOLIDS	202	
	7.6.5	THE SEQUENCE OF DECISIONS FOR THE DESIGN OF A COUNTER-CURRENT WASHING TRAIN WITH HYDROCYCLONES	202	
7.7	APPLICATIONS, CASE STUDIES			
	7.7.1	STARCH WASHING	203	
	7.7.2	Hydrogel washing	205	
	7.7.3	PROBLEMS INVOLVED IN COLLECTING AND INTERPRETING DATA	207	
7.8	Conc	LUSIONS	209	
<b>A</b> 1		CHING NOTES ON THE DEVELOPMENT AND USE OF DE-	211	
A1.1	Pro	BLEMS IN SEPARATION OF IMMISCIBLE LIQUIDS	211	
A1.2	DEV	DEVELOPMENT OF THE DE-OILING HYDROCYCLONE 2		
A1.3	THE	THE SWIRL NUMBER 21		
A1.4	THE	SPLIT RATIO	215	
A1.5	PRES	Pressure drop-flowrate relationship 21		
A1.6	Som	SOME NOTES ON OPERATION OF DE-OILING HYDROCYCLONES 21		

A1.7	SUMMARY OF DE-OILING CYCLONE USE IN PETROLEUM APPLICATIONS	218
A2	TEACHING NOTES ON DEGASSING WITH HYDROCYCLONES	221
A2.1	Introductory remarks	221
A2.2	THE BP DE-GASSING CYCLONE	222
A2.3	THE TULSA/CHEVRON GAS LIQUID CYLINDRICAL CYCLONE	223
A2.4	DE-GASSING AND DE-FOAMING IN THE PULP AND PAPER INDUSTRY	224
A2.5	DE-GASSING OF FUELS AT VEHICLE RE-FUELLING PUMPS	226
A2.6	THE TORE UNIT	226
A2.7	THE EFFECT OF PRESENCE OF GAS ON HYDROCYCLONE SOLID-LIQUID SEPARATION PERFORMANCE	228
A3	SEPARATION, THICKENING, CLASSIFICATION AND WASHING OF WHEAT STARCH WITH HYDROCYCLONES	231
A3.1	Introduction	231
A3.2	SERIES CONNECTIONS IN THE DIRECTION OF OVERFLOW	235
A3.3	SERIES CONNECTIONS IN THE DIRECTION OF UNDERFLOW	237
A3.4	WASHING TRAIN DESIGN RECOMMENDATIONS	240
A3.5	CONCLUSIONS	242